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Materials and Techniques for the Coating of Nineteenth-century Plaster Casts: A Review of Historical Sources

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ABSTRACT

This review paper offers a summary of historical techniques and materials used to produce plaster casts and to treat their surfaces, as found in the historical literature. It reviews a selection of manuals, treatises, and recipe books on the art of the cast makers as well as a selection of patents related to the manufacturing of casts and the coating of their surfaces. The introduction to the review shows how relevant archival, historical, and technical investigation demonstrates that nineteenth century replicas are works of cultural significance in their own right, by means of a synthesis of background information. This paper also offers a brief introduction to plaster moulding and casting as well as a summary of historical recipes on how to treat the surfaces of plaster casts to change the surface properties or their appearance. This review aims therefore to provide a summary of materials used by the nineteenth-century plasterer, and technical information for the use of conservators, researchers, and curators who engage in the care and study of historical plaster casts. Examples from the Victoria and Albert Museum's collection support the information found in the historical literature.

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Technical art history; plaster cast; replica; coating; reproduction; nineteenth century; recipes; review; Victoria and Albert Museum

Introduction

Over the last 20 years, increasing attention has been paid to the study and conservation of cast collections following decades of debate about whether copies are valuable or expendable. Understanding of the 'copy' and 'reproduction' in critical theory encouraged an intellectual shift that influenced the management, curation, and conservation of these collections. In this review the terms copy, reproduction, and replica will be used as synonyms, as in their original meaning, even though over time they have been adopted with different connotations (for example, 'copy' often implies a sense of 'forgery' for the untrained observer). The role and perception of reproductions are still subject of discussion, constituting what Bilbey and Trusted (2010) defined as 'the question of casts'. Loss of detail in, or even destruction of the original means that while Victorian copies were created to have a disseminating role, they have also become acts of preservation (Brown 2016; Payne 2019). Good examples are Elgin's early nineteenth-century casts of the West Frieze of the Parthenon, now housed in the Acropolis Museum, preserving significantly more detail than do the original sculptures (Payne 2019), the Victoria and Albert Museum (hereafter V&A) plaster cast of Trajan's Column (Museum no. REPRO.1864-128)¹ which still holds its decorative

detail, lost to a certain extent on the original in Rome, due to pollution and acid rain, or the loss of the inscription of the ninth-century Dupplin Cross, still visible on its copy placed at the Dupplin parish church, Nittshill and Gatehouse of Fleet (Forsyth and Bourke 1995; Foster and Curtis 2016). In other situations, the original of the copy has been destroyed, representative examples being the sixteenth-century Lubeck relief of Christ washing the Apostles' feet (nineteenth-century copy in the V&A collection, Museum no. REPRO.1889-4), a notable Viking Mammen-style casket destroyed during the Second World War bombing of Dresden in Germany (copies of which exist in several museums), or a decorated Roman distance slab from the Roman Antonine Wall in Scotland, discovered in 1865 but lost in the Great Chicago Fire in 1871 (copy held in The Hunterian collection in Glasgow) (Keppie 1998; Foster and Curtis 2016).

Responses to the question of casts are still highly varied and inconsistent. Some museums have sold part of their collections or transferred them to other institutions, as the New York Metropolitan Museum of Art did in 2006 (Picón, De Puma, and Hemingway 2007). On the other hand, new investments in the redisplay and curation of plaster casts are evident in many institutions. Examples can be found in Athens in the New Acropolis Museum and the Underground,

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in the refurbished Galeries de Moulages at the Cité de l'architecture et du Patrimoine in Paris, in the conservation and redisplay of the Albacini and other historic casts at the Edinburgh College of Art, in plaster storage in the National Museum of Wales (Foster and Curtis 2016) and not least, the refurbishment of the Cast Courts at the V&A.

Nowadays the debate around replicas is further extended to new materials and digital reproductions, such as the ones based on photogrammetry, 3D scanning, and printing. Many museums are already updating their policies (Vulliamy 2016) and developing plans to keep pace with modern digital technologies for documenting, recording, and re-creating works of art (Sharpe 2014; Payne 2015). In some cases, traditional and modern reconstruction techniques are used together for research (Wachowiak, Karas, and Baltrusch 2009), conservation, or restoration purposes (Megens et al. 2011; A "3D Imaging in Cultural Heritage" Conference at the British Museum 2017; Payne 2019). A notable example is the Rijksmuseum in Amsterdam, where these technologies are fully embraced and serve research (Rijksmuseum - Research 2020) and marketing and dissemination purposes (Rijksmuseum 3D Models 2020).

This review paper aims to approach one of the many knowledge gaps still existing in the study of replicas, from a conservation and material studies perspective, by providing a review of the selected technical literature (Table 1) and summarising it. When studying historic casts, it becomes clear that detailed information regarding their technology is sparse. This paper touches on the history and terminology, setting the necessary background information, before looking at the technology of plaster casts through the study of historical manuals. Casts from the Victoria and Albert Museum provide examples that help in the description of the nineteenth-century manufacture, as related to the research of the first author.²

History and terminology

Plaster has long been a term open to interpretations (Kemp 1912). Here, we look at the application of this term in the field of fine arts and yet it can be difficult to generate a shared technical terminology.

Plaster usually refers to the material obtained by burning mineral gypsum, made of calcium sulfate, which can be of different provenance and, therefore, of variable composition falling in the category of 'gypsum plaster'. This is not the same as lime plaster, which is of a different chemical composition (being made from limestone) and is generally harder and more durable than gypsum plasters, slow-setting and relatively less sensitive to water (Bankart 1908). Both gypsum and lime plasters were often combined with

Table 1. List of manuals, historical books and patents reviewed for this study.

Reference	Date
Books	
Pollio, V. (1914) <i>The ten books on architecture</i> . Translated by Morgan, M.H.	30–15 BC
Cennini, C. (1859) <i>Il Libro dell'Arte, o Trattato della Pittura</i> . Translated by: Milanese, G. and C. Firenze: Felice Le Monnier	14th c.
Cellini, B. (1967) <i>The treatises of Benvenuto Cellini on Goldsmithing and Sculpture</i> . Translated by Ashbee, C.R. New York: Dover Publication, Inc.	16th c.
Smith, G. (1810) <i>The Laboratory. Or School of arts</i> . London.	1799–1810
Merrifield, M. P. (1846) <i>The Art of Fresco Painting: As Practised by the Old Italian and Spanish Masters, with a Preliminary Inquiry Into the Nature of the Colours Used in Fresco Painting, with Observation and Notes</i> . C. Gilpin.	1846
Westwood, J. O. (1876) <i>A descriptive catalogue of the fictile ivories in the South Kensington Museum</i> . Science and art department of the committee of council on education, S.K.M.	1876
Frederick, F. F. (1899) <i>Plaster casts and how they are made</i> . New York: New York, W.T. Comstock.	1899
Millar, W. (1899) <i>Plastering. Plain and decorative</i> . Donhead Publishing Ltd 1998 edn. High Holborn, London: B. T. Batsford.	1899
Bankart, G. (1908) <i>The art of the plasterer. An account of the decorative development of the crafts chiefly in England from the XVth to the XVIIIth century with chapters on the stucco of the classic period and of the Italian Renaissance also on sgraffito pargetting Scottish Irish and modern plasterwork</i> . London: B T Batsford 94 High Holborn.	1908
Kemp, W. (1912) <i>The Practical Plasterer. A compendium of Plain and Ornamental Plaster Work</i> . London: Capio Lumen. Reprint, Fourth Edition.	1912
Auerbach, A. (1961) <i>Modelled Sculpture and Plaster Casting</i> . New York: Thomas Yoseloff.	1961
Wager, V. H. (1963) <i>Plaster casting: for the student sculptor</i> . London: Alec Tiranti.	1963
Meilach, D. Z. (1966) <i>Creating with plaster</i> . London: Blandford Press.	1966
Chaney, C. (1973) <i>Plaster mold and model making</i> . New York, London: New York, London: Von Nostrand Reinhold.	1973
de Jonge, L. (1985) <i>The art of doing: Plaster Techniques</i> . Amsterdam, Holland.	1985
Piva, G. (1989) <i>Manuale Pratico di Tecnica Pittorica</i> . Milano.	1989
Turco, T. (1990) <i>Il Gesso. Lavorazione, trasformazione, impieghi</i> . Milano: Hoepli.	1990
Patents	
Greenwood, J. D. and Keene, R. W. (1839) <i>Improvement in cements for forming artificial stone</i> , &c. Patent no. 1361.	1839
Somes, D. E. (1866) <i>Improved composition for forming useful and ornamental articles</i> Patent no. 59154.	1866
Closson, W. B. (1877) <i>Improvement in the art of making molds and their counterparts</i> Patent no. 192112.	1877
Trickey, J. H. (1884) <i>Art or process of and composition for making artificial stone</i> Patent no. 308111.	1884
Laxton, E. T. (1887) <i>Process of hardening and preserving plaster-of-Paris casts and molds and making them impervious to water, &c</i> . Patent no. 371550.	1887
Cléry, A. (1893) <i>A preservative composition, applicable also for the manufacture of artificial stone, statuary and the like</i> Patent no. 16840.	1893
Johnson, W. R. and Nichols, G. (1899) <i>Improvements relating to Gypsum or Plaster of Paris</i> Patent no. 10658.	1899
Wolf, A. (1901) <i>Improvement in Composition for Coating Surfaces</i> Patent no. 15204.	1901
Zolnay, G. J. (1910) <i>Process of Making art models, &c</i> . Patent no. 968505.	1910
de Bas, W. J. (1920) <i>Improvements in Plastic Compositions</i> Patent no. 143768.	1920
Dailey, M. C. and Duffy, E. W. (1948) <i>Gypsum Product</i> Patent no. 446844.	1948
Miller, J. H. (1953) <i>Flexible mold for forming statues with spaced legs</i> Patent no. 660776.	1953
Koblitz, F. F. (1977) <i>Modified Gypsum Composition</i> Patent no. 1 461 812.	1977
Stockton, L. W. (1981) <i>Improvements in or related to gypsum plaster</i> Patent no. 2 053 184 A.	1918

aggregates and additives, and their defining term changed along with the composition of the mixture. Hereafter the term plaster will refer to gypsum plaster mixtures unless stated otherwise.

Plaster has been used in buildings for over 5,000 years (Turco 1990). The use of plasters in art and architecture is connected but also differs in many aspects. For example, in architecture, plaster and *stucco* are considered renderings added to an existing structure, whereas the same terminology relates to different preparations in the field of decorative arts (Kemp 1912).³ Bankart (1908) defined *stucco* as the material based on ‘carbonate of lime, generally the burnt lime-stone or chalk of the rocks and hills’, and for Kemp (1912) *stucco* is a non-durable material used for internal works introduced by the Italians in the UK. The Romans excelled in the preparation of plaster for coating internal walls and Vitruvius in *De Architectura* described ancient *stucco* as composed of well-burned and slaked lime, a little fine sand, and some finely ground unburned lime-stone or white marble dust (Kemp 1912; Morgan 1914). The Italian word *intonaco* can be also misleading; although in English this refers to plain lime plaster, in Italian this term implied the architectural application instead of only referring to a specific composition: it can be both lime- and gypsum-based but it usually has a sand component (Bankart 1908). The lack of specificity and consistency of many authors when describing objects made of *stucco* adds to the confusion (Gapper 1999). The compositions and consequently the definition of these materials was primarily affected by the availability of local materials.

The use of plaster and other moulding materials for casting copies of a wide range of objects is attested as early as the Roman Empire and even Ancient Egypt (Kemp 1912; Frederiksen and Marchand 2010). Plaster was used in ancient Greece and Rome for making death masks, *stucco* sculptures, and copies of sculptures, and for other purposes (Frederiksen and Marchand 2010). According to Pliny, Lysistratus invented the casting technique, later developed for the preparation of the clay models used to produce marble or bronze copies (Rotili 2009).⁴

Historical sources such as Bankart (1908) and Kemp (1912) state that, despite its use since ancient times, plasterwork was not in great use during Mediaeval times, apart from some notable examples, such as the astonishing Moorish ornamental plaster works in the interiors of the celebrated Alhambra of Granada, Spain (Cardell-Fernández and Navarrete-Aguilera 2006); and that it is only in the sixteenth century that there is a notable revival of plaster works, especially in Italy, seeing the Renaissance celebrated artists Raffaello Sanzio (1483–1520) and Giovanni da Udine (1487–1564) experimenting with *stucco duro* (Bankart 1908). This *gesso* (gypsum), or fine hard plaster, soon

spread to France, England, and all over Europe. More recent research demonstrated that although numerous examples of *stucco* can be seen in the early and late medieval period, in Europe and beyond (Pasquini 2002; Sapin 2004; Nenci 2006; Caskey 2007; Danford 2016; Vanni 2019), technical and scientific research on medieval *stuccoes* is still scarce.

According to Kemp (1912), at the turn of the nineteenth century, plaster used in England generally was prepared from a ‘lime sulfate’ found in Derbyshire (Sullivan 2019). Mineral gypsum was first mined commercially in Montmartre, Paris as late as the 1770s, although the mines had been known since the Roman period (Smith 1740), and since then has been commonly known as plaster of Paris, even when not produced there (Turco 1990). Well-known gypsum quarries in the nineteenth century were exploited in many countries – Italy, Switzerland, France, Sicily, the United States, some of the South American states, and Canada (Gypsum – Properties, Definitions and Uses. Vol. 108 1921). Gypsum was found in the UK in the counties of Derbyshire, Cheshire, Nottingham, Cumberland, Westmoreland (now Cumbria), and Isle of Sheppey (Millar 1899; Sullivan 2019). The number of existing types of plaster increased in the twentieth century, due to the development of modern materials such as Crystacal, Jesmonite, and others (Wager 1963; Turco 1990), the discussion of which is outside the scope of this paper.

After the turn of the seventeenth century, collecting casts became a prerequisite for French and, later, German academies, and in subsequent centuries casts were exported to the European colonies of the New World. Mexico City, Boston, New York, and Philadelphia all established academies, cultural centres, and museums, adopting the European taste for classical art (Rotili 2009). Moreover, the relatively low cost of plaster casts, compared to that of original works, allowed the new institutions to build up remarkable plaster cast collections (Disalvo 2012; Lending 2017).

The modern history of ‘copies’ is necessarily linked to the taste for classicism that inspired artists and collectors for centuries, following the idealism of Johann Joachim Winckelmann (1717–1768, German art historian and archaeologist). The collection put together in Rome by the German painter Anton Raphael Mengs (1728–1779, active in Dresden, Rome, and Madrid) and later moved to Dresden, consisted of more than 800 casts of ancient sculpture. This iconic collection became one of the best ways to get an impression of antiquity. Winckelmann’s theories should be carefully applied when considering plaster casts as they cannot be accepted as a precise replacement of an original, the original being made in a much more ‘noble material’ (Dini 2018). Copies, in different materials and dimensions, were widely produced and collected. That they were highly regarded at the time

demonstrates how different the perception of the importance of uniqueness of art in the past was when compared with the twentieth-century perspective (Rotili 2009).

During the nineteenth century, the making and the use of models were extremely important both for educational purposes and commercially. Plaster casts of classical sculpture had been in use as models for the artistic education of students since the earliest art academies in Renaissance Italy (Basile 2014). In Britain, the proliferation of plaster casts and other types of models was enhanced by an intentional project of improving and inspiring local artists and architects, as well as educating the general public. This followed the widespread circulation of copies of the Parthenon Marbles after Phidias's sculptures were exhibited in the British Museum in 1816 to associate the Museum with the Parthenon's *aura* of greatness (Fehlmann 2007). Classical antiquity played a fundamental role in British culture of the time: since the Renaissance, it had served as a model for shaping public opinion and taste, and 'collective memory'⁵ (Fehlmann 2007). Baker, Frederiksen, and Marchand (2010) also discussed the use of casts, in terms of models and reproductions employed among a range of media, as constituting a 'reproductive continuum' or a sort of social memory and witness.

In the second half of the nineteenth century and part of the twentieth, in museums plaster casts were intended for observation, education, handling, documentation, presentation, and art training, not least as part of a concerted effort to improve the quality of industrial design and the taste of nations through the advocacy of universal principles of art (Baker, Frederiksen, and Marchand 2010). The establishment of a representative and commonly accepted canon of art was the main scope of the reproductions and collections such as the one at V&A and others that were modelled on it, were also importantly displaying works that were the canon of sculpture of the second millennium, particularly post-classical. The replicas played a central role in the development of museums not only for the iconic collections such as, for example, the ones in the V&A in London (Figure 1) and the Römisch-Germanisches Zentralmuseum in Mainz, but for many others (Cambareri 2011; Disalvo 2012; Foster and Curtis 2016; Lending 2017).

In Europe, plaster cast collections were appreciated and displayed until the early twentieth century, and afterwards became increasingly forgotten. In museums, many historic replicas received less care than 'authentic' original objects and thus were damaged as and when they came off display (Baker, Frederiksen, and Marchand 2010). The value of casts beyond their role in education was questioned (Bilbey and Trusted 2010): there were concerns that the copies were misinterpreted as originals by the

viewer, the lack of *aura* of the copies, and the missing 'connection' of the object with the artist. The topic of authenticity is a recurring and unsolved discussion in various branches of the fine arts. Basile (2014) on this topic cites both Walter Benjamin's notion of '*aura*', as proper characteristic of 'authentic' pieces of art, and opposite opinions such as that of Bruno Latour (exponent of the postmodernist theory), who suggests that the *aura* could 'migrate' (Dini 2018). The idea of authenticity in the modern sense, along with the disparagement for copies, misleadingly considered as forgeries, was not as great a concern in the nineteenth century, as shown, for example, by the importance of the International Exchange Scheme for the Promotion of Art, established by Henry Cole in 1867 and intended to facilitate the exchange of reproductions across Europe. This ambitious project had a huge impact, having been signed by 15 European rulers (Baker and Richardson 1999; Orvell 2014).

In light of all the above, the V&A cast collection can now be considered unique, having suffered little change up to the present day. The opening of the Cast Courts at the V&A (1873) made a great impression on the public (Figure 1). Collecting as a conscious human activity runs back to the sixteenth century as evidenced by the scholar's study and cabinets of curiosities, which can also link to the visual appearance of museum galleries during the nineteenth century (Pearce 2013). Testimonies of the great impression made by the Cast Courts can be seen in the press of the time:

The boldness of the idea, the height of the apartments, the magnitude of many of the objects with which they are filled, and the beauty of others, all concur to produce a lasting effect. (Anon 1873a)

[...] the new court, [...] a most instructive chapter in the long and varied history recorded in the collection at South Kensington. (Anon 1873b)

[...] it may safely be said that the world does not possess such another. [...] some person will, perhaps, be inclined to question the wisdom of erecting a facsimile of a monument like the Trajan Column, and placing it where it will doubtless be an object of wonder to the public, but will be of very limited benefit to the art student, since, though the column is in two pieces, there is much bas-relief that can hardly be distinguished, much less copied [...]. (Anon 1873c)

At South Kensington, in the two great halls which contains the casts and the copies, there is at present the most extraordinary jumble of works [...] that can possible be imagined. (Anon 1882)

Technologies of the past

Making replicas by casting in plaster was an extremely successful and remunerative business during the



Figure 1. Drawing of the Cast Courts, Room 46a, The West Court, Victoria and Albert Museum, London. About 1873. (D.564-1905). © Victoria and Albert Museum, London/as specified by the rights holder. Source: V&A's Collection Management System.

nineteenth century, and the 1798 Garrard's Act, which was aimed to protect plaster cast makers, did not succeed in stopping the pirating of casts and moulds (Clifford 1992). This led to workshop secrecy around the art of casting and plastering, contributing to the lack of specific information we have available today. The undervalued contribution of plaster casts to cultural heritage, when compared to original works of art and cultural objects, led to reduced interest in the preservation of documentation on the making of these objects. It was argued until recently that they were 'copies' of original objects, less entitled to occupy the already limited space in the galleries than 'real' objects. This perception might also have contributed to the current limited availability of peer-reviewed publications on conservation treatments applied to these objects. The re-evaluation of the role of historic plaster casts can unveil the many

different layers of stories embedded in the replicas: their contextual history of production and circulation, life and afterlife (Foster and Curtis 2016).

The information that this shift of perception and research practice can produce is valuable for those who wish to explore the historical processes, for conservators who try to understand the objects before treating them, as well as for historians and curators who aim to interpret the stories of the past. Archival resources from libraries and museum archives (newspapers articles, photographs, correspondence, workshop catalogues, and transportation documents for the casts, museum registries, and also records of modern cleaning treatments) can often unfold unexpected stories waiting to be told (Figure 2).

Once the replica has been accepted as an object in its own right, it is possible to surpass the biographical approach and consider the scientific value of craft

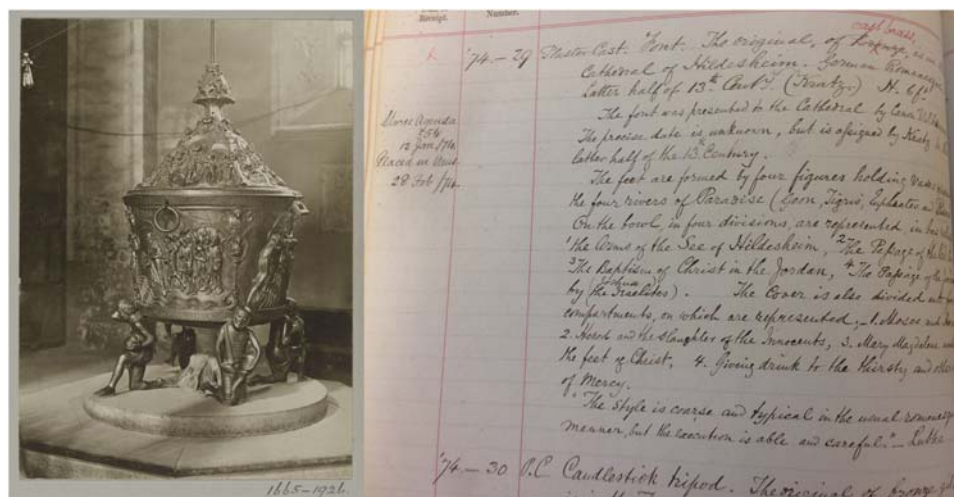


Figure 2. Left: Photograph, the font in the Cathedral of Hildesheim, Germany, gelatine silver print, late nineteenth to early twentieth century (1665–1926). Photographic record: 2016JA0650. © Victoria and Albert Museum, London / as specified by the rights holder. Source: V&A's Collection Management System. Right: Description of the object on the V&A's Register of Acquisition, 28th of February 1874. From the Archive of the Sculpture Department at the Victoria and Albert Museum, London.

technologies and practices, entering the field of technical art history. Behind their creation, circulation, use, and after-life lie a series of specific social networks and relationships that determined why, when, how, and in what circumstances the casts were valued, or not (Curtis 2007; Were 2008).

The practice of writing manuals on the technical arts is as old as the arts themselves. The eighteenth and nineteenth centuries saw increased interest in medieval artists' manuals. Since the nineteenth century, the most popular form of documentary material for the study of painting techniques has been artists' treatises, although a vast amount of the surviving medieval texts on painting technique are copies of earlier writings (Nadolny 2009). Other technical arts have been much less studied:

It is somewhat remarkable that, although most of the useful arts and crafts are fairly well represented in the literature of our own and other languages, the trade of the PLASTERER – which is one of the most ancient of calling – has not adequate representation in technical literature. (Kemp 1912)

When referring to and interpreting historical recipes to define or reproduce the technologies of the past, care must be taken. Where their effects are obvious, artists' recipes may exclude those elements (either 'material' ingredients or 'efficient' instructions) that were considered self-evident at the time. Concentrations and quantities are often vague, and materials are often described through definitions no longer in use, which may sound mysterious to the contemporary reader. The effect of a material, when added into an admixture, is rarely explained. Recipe books are rarely copied word-for-word: they are frequently subject to addition, elimination, and correction, and mistakes (or mistaken translations, as can be seen in the example below

as related to the word *ceralacca*). The nature of certain variations or errors across the text can often tell us something about the context of the compilation. A change in ingredients used in a recipe could be, on the one hand, due to palaeographical problems that resulted in a word being misunderstood and thus being replaced by another well-known one; on the other, it might also correspond to a deliberate technical improvement suggested by the author of the recipe (Bucklow 2009; Neven 2009).

During the recent study of archival resources, two letters proved illuminating on matters of technical practice, and language. The letters, held in the archive of the *Gipsoteca* or '*Museo dei Gessi*' at the University of Sapienza in Rome, were written by Enrico Cantoni (1859–1923) to Emanuel Löwy (1857–1938) on 1 and 13 July 1914. Cantoni was an Italian *formatore* (plaster cast maker) based in Chelsea, London, and Professor Löwy was the Director of the '*Museo dei Gessi*' in Rome. The letters suggest that Löwy ordered a cast from Cantoni, of a head from the collection held at Holkham Hall, Norfolk, England. The cast was reportedly coated with *ceralacca* (which literally would translate as 'sealing wax', but most likely it refers to shellac, a mistake that may have been made due to the similar-sounding word) and Löwy did not like the appearance of the cast.

These letters, and many invoices available in the *Museo dei Gessi* archive, suggest a frequent trade of casts from London to Rome and *vice versa*. The letters seem also to suggest that the British practice of coating plaster casts was not usual in Italy and that the casts would be 'approved' by academics 'as authentic to the original'. The fact that Cantoni refers to a 'mild cost' also suggests that the casts were low-priced additions to the museum collections. Archives

such as these remain almost unexplored on this topic, but further study would surely be revealing.

Letter written on 1 July 1914 (Author's translation):

'Dear Eminent Professor,

I should have answered your letter earlier, but honestly, I had almost forgotten, if not for the reminder by the railway company, that told me that you were waiting for my answer regarding the Plaster Cast that I sent you a few months ago, that you complained about because the plaster cast has been varnished, but given that I make all the plaster casts that I send around the world with the admixture of sealing wax (Author's Note: *ceralacca* in the original letter) and that these are liked by everybody, I thought that these would have been liked by you too. Now I am truly sorry to hear that you do not like them. This admixture that I apply onto the casts is only to make them harder, and to make them washable and to keep them cleaner, therefore you can see that this is nothing bad, at the contrary, it is always good then I hope that you will accept the cast considering that the cost is that mild. Moreover, I will tell you that the cast that I sent you was approved by Professor Waldstein (Author's Note: Sir Charles Waldstein (1856-1927) was an Anglo-American archaeologist; he lectured for many years in Cambridge and was director of the Fitzwilliam Museum) as authentic to the original.

With all my regards,

Yours E. Cantoni'

Letter written on 13 July 1914 (Author's translation):

'Dear Eminent Professor,

Thanks for your letter, as it seems that at the end you were pleased to buy the cast of the Head of Holkham Hall for the Royal University of Rome. I enclose here three copies of the invoice requested by you for the financial formalities with the utmost regards.

Your devoted servant,

E. Cantoni'

Materials and technologies

Seventeen manuals or historical books focused on plaster casting or in some way related to plaster cast technology were reviewed to support the technical and analytical study of casts at the V&A (Table 1). While not an exhaustive selection, the books date from the first century BCE to 1990 and offer a great variety of material descriptions and definitions. The choice of including references that span such a wide timeframe, beyond the focus of this research, was made to encompass the flux of transmission of the recipes, that often are quoted or simply repeated, sometimes with interpretation, from ancient to modern books.

Patents are another source of valuable information (Table 1). The patents consulted date from 1839 to 1981 and were registered in the UK, Canada, and the US. They show a coeval interest and perceived value in finding solutions and guarding that information, and often provide more details than manuals.

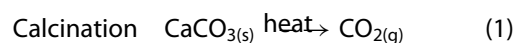
In the following sections, a summary of the information learned from the selection of manuals and patents is presented. A special focus is given to the coating of plaster casts, a little-studied area.

Making of gypsum

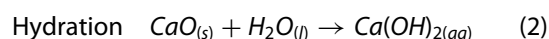
The useful property of gypsum is that following calcination it can be reduced to a powder to create gypsum plaster, which will again become a cohesive solid by being mixed with water and afterwards allowed to dry (Turco 1990). According to Millar (1899), mineral gypsum in the Tertiary strata of Montmartre, Paris, usually contained 10% calcium carbonate, not always in intimate union with the sulfate, but interspersed in grains. 'Plaster of Paris' and other types of gypsum plaster are prepared by drying gypsum, $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$, traditionally firing it in kilns, driving off most of the water of crystallization and leaving the powder very reactive (Bankart 1908; Wager 1963).

While the word plaster commonly refers to a variety of preparations, the main chemical types are **lime plaster** and **gypsum plaster**. For the most part, the methods being referred to in this article relate to gypsum plaster. The two types can be differentiated as follows:

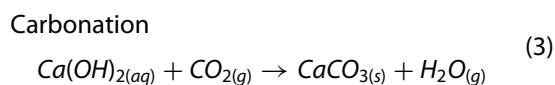
Lime plaster is made by heating calcium carbonate (limestone) to produce calcium oxide (quicklime):



Then, water is added to form calcium hydroxide (slaked lime) which forms the plaster mix:



Lime plaster sets chemically by reacting with carbon dioxide (CO_2) present in the air:



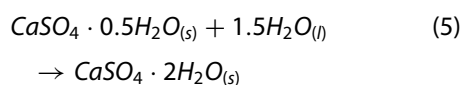
Natural or mineral gypsum is the mineral constituted by calcium sulfate and two molecules of crystallization water (calcium sulfate dihydrate, $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$). **Gypsum plaster** is a hemihydrate of calcium sulfate and is prepared by the partial calcination of gypsum (4), which achieves solid state after

(re)hydration (5).

Calcination



(Re)hydration



The mineral is easily scratched and highly porous, vulnerable to mechanical damage, discolouration by dirt penetration, and softening and disintegration caused by the presence of moisture (Palache, Berman, and Frondel 1951; Cox, Price, and Harte 1974). It has a sedimentary genesis and quarries can be found in Spain, Egypt, Utah, and Colorado, Russia, France, England, Poland, and Italy (Cox, Price, and Harte 1974; Madonia and Forti 2003). If the mineral is quite pure, its colour is white, as its crystals are transparent and colourless, but impurities can change its colour from yellowish to brown and grey to dark (Cox, Price, and Harte 1974; Turco 1990). The natural impurities can include small amounts of calcium carbonate, clay (hydrous aluminium silicate) and other silicates, iron oxide, rock salt (sodium chloride) or other water-soluble sulfates, sulfur, strontium, and other elements (Bankart 1908; Auerbach 1961).

When natural gypsum is heated to a temperature between 107–200 °C⁶ it loses about 75% of the water of crystallization to become the hemihydrate (also known as modelling plaster in fine arts) (Gypsum – Properties, Definitions and Uses. Vol. 108 1921; Turco 1990). During the process of hydration, water is mixed into the gypsum plaster, providing a short working time for procedures like casting, before it hardens and reforms into solid as a mass of needle-like monoclinic crystals (Figure 3) (Cox, Price, and Harte 1974). These crystals are arranged randomly, and interlock and intertwine to hold together at points of contact by inter-crystalline attractive forces which account, at least in part, for the strength of set plaster. The solidity of the hardened mass depends on the felting of the crystals (greater or less according to the amount of water used for the mix). Excess water evaporating leaves voids or pores and the greater the porosity, the weaker the resulting structure (Turco 1990; Barclay 2002). During the setting process, the conversion to the dihydrate is accompanied by the generation of heat (about 3.900 Cal/mol) and a slight increase in volume due to thermal expansion (Millar 1899; Bankart 1908; Turco 1990). There are two allotropic varieties (different physical forms of the same chemical substance), both highly water-soluble: the fast setting α and the slow one β . The property of expanding and returning to near its original volume upon cooling is one of the reasons why it can be used to pick up small details from a positive form

(Meilach 1966; Beale, Craine, and Forsythe 1977; Payne 2020).

The purpose for which the plaster is to be used influences the selection of qualities, which are defined by the manufacture of the material. The quality of the gypsum, the atmospheric temperature, the calcining temperature, the rate of grinding, the storage conditions, and the water/plaster ratio massively affect the setting time and therefore the quality of the final product (Turco 1990). Grinding is described in many different sources and the degree of grinding will change the material's mechanical properties. The plaster worker should be provided with at least two grades of plaster. A fine grade [...] for surfaces, and a larger quantity of a cheaper grade for strengthening moulds and casts [...] (Frederick 1899). Cennini (c. 1360 – before 1427) suggests adding some *bolo Armenico* (Armenian bole, a clay more commonly associated with gilding) at this stage to add some colour (Cennini 1859).

In mixing, the water-to-plaster ratio varies, and the admixtures are mostly done by feel and experience, but are generally one part of water and two of plaster (Meilach 1966). [...] *Water should be as pure as procurable, and especially free from those salts, which absorb moisture from the atmosphere [...]* (Kemp 1912).

Processing and casting with gypsum plaster

Casting involves pouring into a mould a liquid material, which hardens and takes the shape of the mould. This produces a solid object or one with an interior cavity and walls of variable thickness, depending upon how much plaster is used and how well it is distributed. Moulds can be made of sand, clay, plaster, gelatine, *gutta-percha*, and modern flexible materials.

As with sculptors in earlier centuries, during the nineteenth century gypsum plaster was frequently used in both moulding and casting to transfer sculptor's works made in plastic materials, such as wax, and clay, into a more durable form (Meilach 1966).

Gypsum plaster has thus been employed to copy and mimic a wide variety of materials. It is extremely easy to use and dries very quickly, but it also has the quality of penetrating every detail. Nevertheless, it is not one of the 'noble' materials that were used for centuries to create great works of art; plaster is fragile and impermanent. It has always been used as an aid for many branches of art, due to the rapidity with which reproductions can be made (de Jonge 1985).

Traditionally, plaster has been modified during or after casting, to impart hardening and water repellence (Bankart 1908; Turco 1990). The materials are selected for a specific purpose considering the desired performances of these during the processing

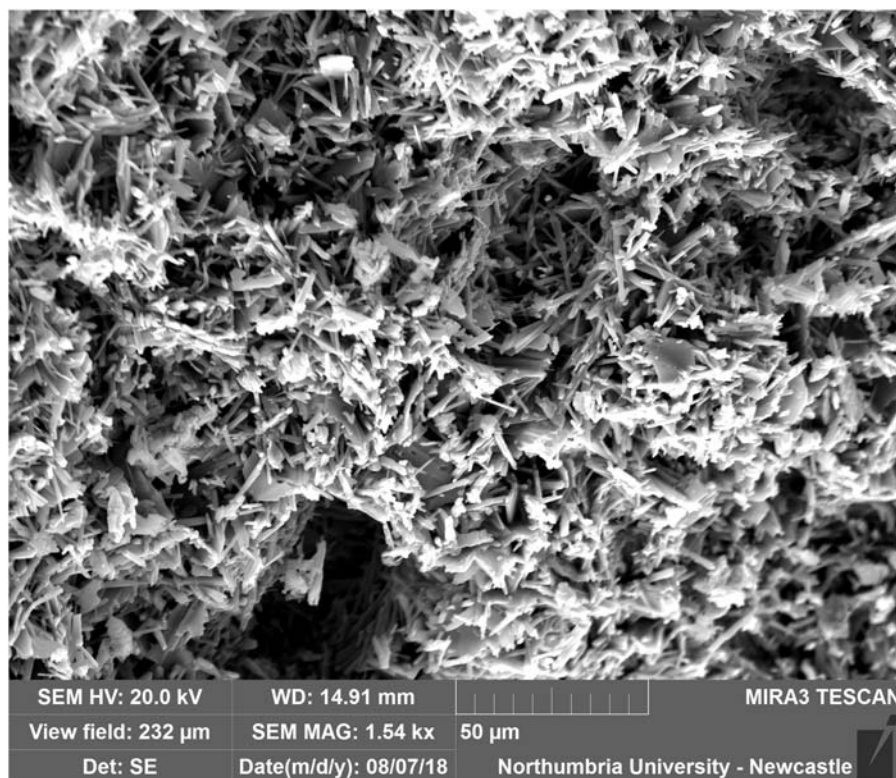


Figure 3. The tabular (needle-like) structure of plaster imaged at x1540 in a scanning electron microscope using back scattered electrons. Example from a sample taken from the plaster cast of a tombstone, in the V&A collection (REPRO.1873-380).

and their afterlife. In particular, the following effects can be obtained:

- **Acceleration of setting time** in the presence of alum, potassium, zinc sulfate, nitrate, chloride salts and acids, and calcium and barium carbonate (Bankart 1908; Wager 1963; Turco 1990);
- **Improvement of mechanical or aesthetic properties (texture, density, strength, workability)**, traditionally straw, hemp, sawdust, hair, and bulking agents like sand or pulverised marble are blended in the plaster to improve its strength and change its colour and texture (Millar 1899; Meilach 1966). To improve hardness, additives such as silicates, carbonates, sulfates, barite, and alum will combine with each other or with the plaster to form compounds of greater hardness than gypsum (Turco 1990). A similar effect is achieved by adding, before or during the mixing, substances that do not react but fill the pores of the plaster (gelatine solutions, casein, Arabic gum, albumin, methylcellulose, sodium alginates, emulsions and solutions of synthetic resins, and soapy solutions) (Westwood 1876; Frederick 1899; Turco 1990). Other additives that are mentioned for improving the resistance of plaster are powder and marshmallow root, sodium bisulfite, ammonium triborate, metal oxides, and phosphates or sulfates (Frederick 1899; Turco 1990).
- **Retarding of the setting time:** with the addition of organic materials with a high molecular weight such

as glues, caseins, keratins, pectin, albumin, gum Arabic, gelatine, hydrolysed proteins, molasses, decomposition products of albuminoids, hydrolysis products from animal residues, products of reactions of amino acids with formaldehyde, powder and marshmallow root, and tannin (Smith 1740; Frederick 1899; Turco 1990). Substances that decrease the solubility of gypsum can also be used, such as glycerine, alcohol, acetone, ether, sugar, nitric, acetic, phosphoric, boric, lactic acids and their salts, including alkaline and calcium salts, and sodium carbonate (Turco 1990). Substances modifying the crystallographic structure of gypsum are also described: calcium acetate, magnesium carbonate and calcium, also borax, lime, stale beer, and ammonia (Bankart 1908). Additives, such as waxy and resinous emulsions, alginates, carboxymethylcellulose, and sodium silicate, slow the setting by behaving as protective colloids (Smith 1740; Turco 1990).

Occasionally, additives lead to efflorescence, the formation of cracks and blisters, and the loss of cohesion (Meilach 1966). Impurities or half-baked particles have a negative effect on the setting of the plaster, causing incomplete crystallization and weakening of the structure. This is due to the reduced capacity of the material to absorb water when the impurities are present (Turco 1990).

To provide additional support for larger casts, armatures of different materials are added. Kemp (1912) and

Wager (1963) mentioned the use of fibres, wood, and metal nails. Payne (2020) refers to Desachy⁷, who produced thin, hollow casts by applying plaster strengthened with layers of jute inside the mould. This formed a lighter, tougher cast than those constructed from traditional methods. The V&A collection houses several casts by Desachy, for example Michelangelo's *Moses* (REPRO.1858-278) and Donatello's *St George* (REPRO.1864-36). The *Moses* also had the addition of wooden battens to help support the structure (Hubbard 2015; Graepler and Ruppel 2019). Zolnay (1910) in the patent 'Process of Making art models' mentioned the use of asbestos, a fibrous needle-like mineral widely used before being banned in many countries due to its health-related hazards, as reinforcing material, which is also found in Dailey and Duffy (1948) and Koblitiz (1977) (see Table 3).

Due to its qualities, gypsum plaster is suitable for the dual purpose of making both casts and the moulds for forming those casts. Although innumerable techniques for plastering and casting in plaster can be found in the literature, most of the nineteenth-century plaster casts were produced by workshops using similar production methods. Rotili (2009) suggests that, although in the sixteenth century plaster casting was considered expensive and difficult, in the following centuries the techniques were simplified and thus became more economical and generally were consistent over the centuries. Of the different techniques available, which one is used depends on the characteristics of the object to be reproduced, such as its shape, material, and the presence of undercuts, on the availability of time and resources, and also on the necessity of reusing the mould (Smith 1740; Wager 1963). There are historically four main methods that can be used to produce a plaster cast, and these are named by the type of mould produced during the moulding process: waste; gelatine, jelly, or elastic; piece; and wax mould. Other casting methods, such as paper or clay squeeze moulds, are known to have been in use in the nineteenth century but are not discussed in this review as they were not presented in the sources selected for this paper.

- A **waste mould** must be broken or wasted before the cast can be extracted. Plaster is applied to the model and when set, the model is withdrawn and destroyed in the process. The mould created is filled with fresh plaster and broken away⁸ once the interior plaster has set (Auerbach 1961; Wager 1963; Meilach 1966). Plaster waste moulding is a method used for moulding clay models in the round (Millar 1899). Waste moulds are used to save the expense of piece-moulding clay models when only one cast is required. Wax can be used

as the waste material for small, flat, and delicate work (Millar 1899; Beale, Craine, and Forsythe 1977).

- A **gelatine, jelly, or elastic mould** is made of gelatine, obtained by boiling in water the collagenous tissues of animal bones, tendons, and ligaments, the cellular tissues, the skin, and the serous membranes (Frederick 1899). The resilience of the material permits making casts with undercuts, with no fear of adherence of mould or cast, or of the cast becoming 'locked in' by the mould. Several casts can be made, but the gelatine can only be kept for a short time (Kemp 1912; Wager 1963). The gypsum plaster as it sets warms up and expands a little. The increased temperature and pressure make the gelatine malleable. Tomlinson (1852) points out that gelatine does not store well. Frederick (1899) suggests working only with 'the best white glue'⁹, or with glue and molasses (proportion of 16 ounces of glue to 14 ounces of molasses) and Kemp (1912) works with *one part of good glue and two parts of molasses (treacle), by weight, melted together*.
- A **piece mould** is made up of several plaster pieces which take the imprint of the surface to be reproduced. Once these parts are placed together, they form the complete mould, and the mould can be kept indefinitely. Piece moulds are used for producing casts from original models that are in the round or undercut, and where it is impracticable to mould them in one or two pieces. Numerous pieces of mould are made and carefully fitted together. Each section is made individually so it fits perfectly against the section next to it. Pieces are held together by a separate casing of plaster (*mother mould*). All the mould pieces are then greased thoroughly with a releasing (or separating) agent and assembled into the mother mould and the whole tied together. The casting material is poured into the mould through an opening and allowed to harden. Each piece of the mould is then carefully removed and the finished cast results. Plaster is more adaptable for forming a piece mould than other sculpting materials (Millar 1899). This method is imperative where moulds have to be kept in stock over a period, as well as for huge objects (Wager 1963; Meilach 1966; Cellini 1967).
- **Wax moulds** were used for taking an impression of metal, wood, stone, or plaster models for reference purposes. Millar (1899) provided four different recipes for producing wax moulds. Frederick (1899) also describes the wax mould as made of one part of rosin and three parts of white wax (or melt paraffin wax and add a little sweet oil and whiting). Kemp (1912) suggests the following wax admixture: ½ lb. of beeswax, ½ lb. of black resin, and 6 oz. of tallow.

The sources suggest that the majority of casts were made from gypsum plaster using the 'piece moulding

technique' (Cennini 1859; Frederick 1899; Wager 1963). However, during the recent renovation project of the Cast Courts at the V&A, evidence of the extensive use of the gelatine mould technique has been found to a greater extent than had been predicted. Borges (2020) demonstrates the findings in many casts at the V&A: traces of gelatine were found, for example, in the Pisano pulpits (REPRO.1865-52 and REPRO.1864-83) and the Portico de la Gloria (REPRO.1866-50).

The application of separating agent to the object to be reproduced is immensely important for the success of the procedure. Gelatine and wax moulds often do not require a 'separating interface' between the mould and the original piece, however, these techniques do not produce lasting moulds. As for the piece and waste techniques, the objects must be oiled, shellacked, or painted (Frederick 1899). Although the separating agent cannot itself be considered as a cast's coating layer, the possibility of the separating agent being transferred onto the cast surface during the casting must be taken into account, at least to be able to discriminate between the two. Also, the possibility of the cast being used as a model for subsequent casts and therefore being coated with a releasing agent might result in an additional layer. A summary of materials used as separating agent can be found in Table 2.

Coating plaster casts

The cast repeats the shape of the original and can be treated to look like stone, bronze, and other costly materials (Figure 4) (Auerbach 1961). In 1907, in the

speech for the opening of Museum of Archaeology of the University of Jena, Botho Gräf (1857–1917) said that 'a cast made of white plaster is sincere, whereas one with colour is a deceptive plaything' (Bankel 2004). Histories around the use of coatings were many and varied: white and uncoated plaster casts seem mainly to be found in classical and archaeological collections, where the whiteness of the plaster is prized for the perfection it conveys (see for example the cast collection in the Ashmolean Museum, the Universities' *Gipsoteca* in Italy, and Greek & Roman Plaster Cast Collections in Berlin), whereas collections of later European art and architecture are often coated to mimic the surfaces of the originals coinciding with aims of improving the general public's understanding of iconic works from the post-classical world (Bankel 2004; Graepler and Ruppel 2019). The practice of coating the casts made of plaster during the nineteenth century, although not always well-received (Lending 2017), had the double purpose of changing their appearance and, importantly, of protecting this porous and water-sensitive material from the environment, therefore making it more durable. Coatings were applied by brush, spray, or by dipping the object into a bath of the prepared solution (Wager 1963; Turco 1990) and were applied warm or cold onto the surface of the casts that might be or might not be previously heated (Millar 1899; de Jonge 1985; Turco 1990). Developing concern during the nineteenth century about the preservation of the pure white plasters gave rise to increased interest in coatings, although plaster casts purposely produced for schools of arts and as such were often not treated

Table 2. Summary of materials used as separating agent as from the reviewed sources.

Separating agent	Description	References
Clay water	Is simply clay and water up to the consistency of cream	Frederick (1899)
Fat (animal)	The fats should be dissolved by heat, and then sufficient paraffin oil added until of a creamy consistency.	Millar (1899)
Lard	Soft lard	Cellini (1967) (16th c.)
	Lard with and without sweet oil; the addition of paraffin oil to these oils renders them softer, cleaner, and free to work.	Millar (1899)
	Equal parts of lard and tallow	Frederick (1899)
Oil	Russian tallow and sweet oil	Millar (1899)
	Chalk oil is also used for wax moulds.	Millar (1899)
	Olive oil	Kemp (1912)
	Automotive oil (30WT)	Chaney (1973)
Shellac	Shellac in methylated spirits. Fill a bottle with finely ribbed shellac, heat this up <i>au bain Marie</i> without the cork on the bottle. Shake thoroughly and use when is cooled down	de Jonge (1985)
Soap solution	Put one pint of water on to boil and cut into this as much white castile soap as will dissolve.	Frederick (1899)
	Green liquid soap	Kemp (1912)
	Made by boiling two large tablespoons of best black soft soap in a pint of water. This is then to be used cold.	Wager (1963)
	Shellac them while damp, with two coats. Then grease with olive oil mixed with tallow.	
	English Crown Soap dissolved in warm water and kept available in cool liquid condition	Wager (1963)
	Made dissolving liquid (green) soap or a bar of soap in hot water and leaving this to stand for about a day.	de Jonge (1985)
	The proportions are usually one part soap to two parts of water	
Stearic acid	One part of stearic acid (or stearine) is melted in a water bath, and about 5 parts of alcohol or benzene is added, in which it dissolved to a clear solution.	Millar (1899)
	¼ lb. of stearic acid in 1 pint of kerosene, melted by warming, removed from the heat, kerosene gradually stirred	Chaney (1973)
Suet solution	Made by dissolving fresh mutton suet by gentle heat, then adding as much paraffin oil as will keep it in a soft cream state when cold.	Millar (1899)
Vaseline	It may be melted with carbon tetrachloride to simplify the spreading	Meilach (1966), de Jonge (1985)
Wax	Author note: Not specified. To be applied onto the model surface.	Meilach (1966)



Figure 4. Plaster casts of a lead statuette figure of a seated girl (A.2-1946) made in the Sculpture Conservation Studio at the V&A to illustrate how the different coatings were used to deceive the observer. © Victoria and Albert Museum, London/as specified by the rights holder.

with a finishing coat, being considered expendable (Graepler and Ruppel 2019).

Whether to change the appearance or just to protect, numerous treatments were in use. Size, gelatine, water, or milk were used to close the pores of the plaster, as well as white shellac, dextrin, beeswax, and linseed oil. Recipes for coatings suggest among other materials: animal glue, linseed oil, milk, waxes, tree resins, and pigmented paint. They were used alone, in successive layers, or admixtures (Wager 1963).

Modern sources such as Roberts (1968) and Turco (1990), also quoting earlier publications, summarise surface treatments as:

- film-forming materials such as soaps (stearates, oleate, calcium palmitate, iodine, ammonium stearates), animal or vegetable oils, waxes (melted or in solution with appropriate solvents), greasy and synthetic paints, synthetic resins (in solution or emulsion), natural and synthetic elastic rubber (dissolved in suitable solvents)¹⁰, fluates, and silicates. The fundamental constituent of these coating materials is the film-forming base which attaches itself to the substrate to which it is applied. To adhere to the substrate, the film must be applied in the form of a liquid that wets the substrate and then cures to a solid state (Roberts 1968). Their concentration should be intermediate, allow the material to form a film, but at the same time to penetrate the plaster enough to interact with it;
- materials that react with the outermost calcium sulfate molecules and therefore change the

properties of the surface (improving the hardness and water sensitivity for example), such as barium and sodium chloride, ammonium phosphate and oxalate, calcium carbonate, lead acetate, and barite. This group of materials can also be used as an additive in the plaster mixture (Auerbach 1961; Wager 1963; Turco 1990).

The finishing layer or coating for plaster casts is different from the usual definition for objects such as paintings. In the latter, the substrate (i.e. wood, canvas, etc.) can be covered by one or more preparation layers that would not exist independently as a surface layer, and the finishing or paint layer is applied on top of those (Roberts 1968; Carlyle et al. 1995).

For plaster casts, every treatment applied to their surface can be a 'coating' or a finishing layer in itself. A plaster cast, when extracted from the mould, already represents the complete form not dependent on the 'building up of layers' on its surface as is the case in the stratigraphy of a painting. Therefore, every treatment applied to the surface of casts can allegedly be the outer surface layer or coating. Moreover, there is not a 'rule' in terms of sequencing of the layers (Auerbach 1961; Roberts 1968). According to Auerbach (1961), a new cast will usually take some weeks at least to dry out thoroughly in the atmosphere. The quality of the gypsum, the water/plaster ratio, and the atmospheric conditions all have an impact on the drying time. Nevertheless, the application of finishing could be done either straight after the casting or even months later.



Figure 5. Detail of a plaster cast of a relief on the outside of Notre-Dame Cathedral in Paris, in the V&A collection (REPRO.A.1916-3152). A closer look during a sampling campaign enabled the identification marks and scratches due to the use of tools. © Victoria and Albert Museum, London/as specified by the rights holder.

The appearance of the surface of the cast also depends on whether a surface has had further preparation before the application of a coating and can consist of either mechanical smoothing (such as sanding) or solvent pre-treatment. Sanding of plaster products can be performed in dry conditions, with water (which will cause a slight dissolution of the surface) and with oil or any oily materials (Turco 1990). The level of sanding (coarse to fine) and the technique used to polish the cast affect the final appearance of the surface (from matt to shiny), as well as the porosity of the surface; the use of tools to remove leftover material can be sometimes still observed in the finished cast (a closer look at the cast surface can reveal tool marks such as rasps, see Figure 5).

The above purposes can be achieved with one or more layers of the same or different materials and there is not a well-defined hierarchy or order in which these layers were usually applied. This is clear when reading the historical recipes, as the application of the same materials is suggested at different stages (Millar 1899; Bankart 1908; Wager 1963). Millar (1899), says that casts which are to be polished by friction with other substances should be made as hard as possible, suggesting that a hardening treatment can be applied *before* the polishing. A coating could ideally accomplish multiple desired effects: ‘sealing the pores’ and ‘waterproofing’ for example might seem the same action, but, although in some case the two can be achieved at the same time, one property does not imply the other, as clear from the fact that the two purposes are separately mentioned in the

recipes (Millar 1899; Turco 1990). Tables 3 and 4 summarise the recipes retrieved from the books and other archive resources reviewed for this study. We can generally categorise the coating through the intended function, which can be to seal the pores, to waterproof the surface, to harden the surface, and to change the appearance (Graepler and Ruppel 2019).

The purpose of **sealing the pores** is generally achieved by most of the materials used for coating, with different results depending on the materials and the concentration of the coating. To close the pores of the plaster cast there is a wide range of materials that can be applied onto the plaster surface and they work either by penetrating the pores and filling them rather than by creating a film onto the surface and consequently preventing the dust and moisture from entering into the pores (Figure 6).

The task of making the casts **resistant to water** or ‘washable’ has been investigated for at least two centuries. Traditional treatments with waxes and wax mixed with turpentine (Auerbach 1961; Wager 1963) are very effective for waterproofing and for providing a translucent appearance and fine aesthetic effect. In the mid-nineteenth century, the care of large collections of plaster casts had become a topic of concern, particularly in the university collections in Germany. Scientific research into the investigation of protective treatments for casts was supported by the Prussian Government and a prize was awarded to W. Reissig, of Darmstadt, for his development of a method for treating casts such that they would become water-resistant. This involved converting the surface of the calcium sulfate cast into either barium sulfate or

Table 3. Summary of recipes retrieved from the sources reviewed for this study.

Description	Notes	Application	References
Waterproofing the surface			
Boil 1 oz. pure white wax, 2 ozs. Venice turpentine. Add half pint spirits turpentine	Invented by Mr F. D. Millet	Brush	Frederick (1899)
The lime sulfate is changed into baryta sulfate and caustic lime by means of baryta water. Exposure in the air subsequently changes the caustic lime into lime carbonate. This is best worked by using a zinc vessel with a zinc grating 1 ½ m from the bottom, and a close-fitting lid. Soft water, 54 to 77 °F. Every 25 gallons of water add 8 lbs. fused oil or 14 lbs. crystallised pure hydrated barium oxide and 0.6 lb. lime. The dipping should be affected with rapidity. Hollow casts after being saturated are filled with the solution and suspended in the bath, and the vessel is closed from two to twelve days, according to the silicate stratum required	Invented by Dr Reissig, of Darmstadt	Dip or brush	Millar (1899), Kemp (1912)
To harden by means of the silicate of potash solution, convert the lime sulfate into lime silicate by using a diluted solution of potash Silicate containing free potash. 10% solution of caustic potash in water, heat and add pure silicic acid (free from iron). After cooling the solution deposits silicated potash and alumina. Before using, throw in some pieces of pure potash, or add about 2% of the potash solution	Invented by Dr Reissig, of Darmstadt	Dip or sponge	Millar (1899), Kemp (1912)
Immerse the cast or throw upon it in a fine spray a hot solution of a soap prepared from stearic acid and soda lye in ten times its quantity, by weight, of hot water	Invented by Jacobsen	Dip or spray	Millar (1899)
Apply a solution of borax and alum to harden the plaster, and apply soluble precipitates (salts of barium, calcium, and strontium), by which the minutest pores are filled up and the surface rendered hard	Patent by F. von Dechend (1814–1890)	Brush	Millar (1899)
Mica, rendered perfectly white by boiling with hydrochloric acid or calcining, mixed with dilute collodion to the consistency of oil - paint	Invented by Shellhass	Brush	Millar (1899)
Boil p. 6 of linseed oil, p. 1 of litharge and p. 1 of wax. Brush on hot, when dry second coat. Allow to dry and then polish	-	Brush	Wager (1963)
Coating paraffin or white wax or spermaceti in white spirit, petrol or petroleum	-	Brush	Turco (1990)
Waxy encaustics or aqueous wax emulsions (alone or with emulsions of white shellac and resins) These emulsions must be very concentrated or thickened with Arabic gum, alginates, methylcellulose, carboxymethylcellulose, animal glues, etc.	-	Brush	Turco (1990)
Dry the cast in the oven (80–90 °C) and then immerse it in oil or paint (50–60 °C); the plaster must be totally impregnated and subsequently dried in a well-ventilated area. It dips again for half the time and dries again	Yellow-brown colour	Dip	Turco (1990)
Diluted solution of aluminium soap in turpentine and petrol essence	-	Brush	Turco (1990)
Dissolve casein with hydrated lime or slaked lime. A small amount of barium peroxide can be added to the mixture	-	Brush	Turco (1990)
Casein p. 75, slaked lime p. 17, anhydrous sodium carbonate, p. 8 barium peroxide p. 1.5, water p. 280. Peroxide is added eventually. The final product should be used in a maximum of 20 minute	-	Brush	Turco (1990)
p. 3 of rosin in p. 5 of water and one part of soda. If instead of soda an ammonia is required, a long heating at 30–100 °C is necessary	-	Brush	Turco (1990)
p. 24 alum, p. 4 white soap, p. 2 Arabic gum, p. 6 gelatine (12% solution), p. 24 water	-	Brush	Turco (1990)
p. 25 oily paint, p. 35 solvent naphtha, p. 40 carbon tetrachloride, p. 150 denatured alcohol, p. 50 soap, p. 700 water (apply keeping the product in a water bath)	-	Brush	Turco (1990)
p. 1 fish glue, p. 420 water, p. 30 sodium sulphoricinate, p. 49 stearic acid OR p. 432 oleic acid, p. 122 ammonia at 28 °Bé, p. 61 denatured alcohol 95% by volume, p. 43 aluminium chloride, p. 37 calcium chloride, p. 305 water)	-	Brush	Turco (1990)
p. 20 paraffin, p. 30 ozocerite, p. 20 white spirit, p. 150 toluol	-	Brush	Turco (1990)
p. 2.4 ozocerite, p. 8.9 paraffin (50–52 °C), p. 2.5 olein, p. 2.2 morpholine, p. 84 water	-	Brush	Turco (1990)
p. 120 paraffin, p. 12 stearic acid, p. 6 ammonia at 26 °Bé, 30% p. 40 silicone emulsion, p. 180 water. Paraffin is heated to 55 °C, ammonia is added and then water. After cooling, the silicone is added. For the application it is diluted with water	-	Brush	Turco (1990)
p. 90 ozocerite, p. 14 ammonium linoleate, p. 400 water, 30% p. 30 silicone emulsion	-	Brush	Turco (1990)
Hardening the surface			
A bath of borax (baborate of soda) applied in the proportion of about one pound to every gallon of boiling water	Patent: Process of hardening and preserving plaster-of-Paris casts and molds and making them impervious to water, &c.	Dip	Laxton (1887)

(Continued)

Table 3. Continued.

Description	Notes	Application	References
<i>A bath of melted pure white wax, paraffine by preference, as this keeps its whiteness better than any other</i>	<i>Patent: Process of hardening and preserving plaster-of-Paris casts and molds and making them impervious to water, &c.</i>	Dip	Laxton (1887)
<i>A neutral soap of stearic acid and caustic soda is prepared and dissolved in about ten times its weight of hot water.</i>	-	Dip or brush	Millar (1899)
<i>Equal parts of stearine and resin and containing per each kilogramme, 0.20 g of bitumen, preferably Jew's pitch, 0.50 g of benzoin, preferably from Sumatra, 0.05 g of creosote, preferably from beech and also if it is desirable, any colouring matter. Heated in a proper recipient to a complete solution and suitably stirred to produce a homogeneous mixing of composition. In the bath for 5 to 30 minutes, depending on the nature, thickness etc. of the article as well as the degree of hardening desired. This composition may be employed for decorating purposes being capable of being made in various colours by the addition of suitable colours [...]</i>	Patent	Brush	Wolf (1901)
<i>[...] a compound made of gum, bees-wax, and gasoline, the latter rendering the molded article impervious, washable, and extraordinarily hard. [...] raw asbestos pulp, kaolin, whiting, or plaster of Paris with dissolved glue, flour paste, and linseed oil, all in such proportions as to yield a paste of about the consistency of dough. The above plastic layer is then backed by strips 2 of sheet asbestos, adhesively applied thereto. [...] The above product is then permitted to dry, and when dry it is saturated with heated paraffin, oxide of lead, and a suitable pigment by which it is rendered impervious, washable, and of the desired colour</i>	Patent	Brush	Zolnay (1910)
<i>Immerse a plaster cast object in a saturated solution of alum at 90 °C</i>	-	Dip	Wager (1963)
<i>40–50% silicone solution in p. 5 water, p. 15 potassium silicate, p. 80 water</i>	-	Dip or brush	Turco (1990)
<i>Dry and heated casts are sprayed with a concentrated ammonia solution that helps the subsequent action of hardening baths based on alkaline borates and salts capable of forming double salts with those of ammonia</i>	-	Spray and dip	Turco (1990)
<i>Immersion in an ammonium triborate solution which is obtained by saturating a concentrated and warm solution of boric acid with ammonia.</i>	-	Dip	Turco (1990)
<i>Small objects are dried in an oven at 100 °C and then immersed in a 20–30% silicate solution (sodium silicate with silica and oxide ratio 3.2–3.3)</i>	-	Dip or brush	Turco (1990)
<i>Applying a saturated borax solution in water (120 g salt in crystals for each litre of water)</i>	-	Dip or brush	Turco (1990)
<i>p. 2 Slaked lime, p. 8 casein, p. 90 water</i>	-	Dip or brush	Turco (1990)
<i>p. 5 casein, p. 5 slaked lime, p. 1 Arabian gum, p. 4 sodium silicate, p. 70–100 water</i>	-	Dip or brush	Turco (1990)
<i>The objects dried in the oven are immersed, while still having a temperature of 70–80 °C, in a hot saturated solution of barite (barium oxide), then they start to dry again by repeating the treatment several times</i>	-	Dip or brush	Turco (1990)
non-specified Purposes			
<i>Coats with hot glue sizing – the first being quite thin. Allow this to dry thoroughly and cover it with one or more coat of white shellac</i>	-	Brush	Frederick (1899)
<i>White wax dissolved in olive oil, or paraffin wax. Polish with French chalk and cotton wool</i>	-	Brush or dip	Millar (1899)
<i>White beeswax and glycerine. Polish with French chalk and cotton wool or sable hairbrushes</i>	-	Brush or dip	Millar (1899)
<i>Plaster gauged with milk and water</i>	-	Brush or dip	Millar (1899)
<i>Dissolve ½ oz. of soft soap in 1 quart of water, and 1 oz. of white wax. Polish with soft rag and French chalk</i>	-	Brush or dip	Millar (1899)
<i>Coat of white shellac, then a good coating of boiled soft soap, and polish a soft dry rag</i>	-	Brush	Millar (1899)
<i>1 gill of Copal varnish with 1 oz. of patent driers and turpentine</i>	-	Brush	Millar (1899)
<i>p. 100 water, p. 12 best hard shellac, and p. 4 of borax. Used alone or mixed with a small portion of linseed oil and a few drops of turpentine</i>	-	Brush	Millar (1899)
<i>Dissolve India rubber in naphtha</i>	-	Brush	Millar (1899)
<i>Melt ½ oz. of tin and ½ oz. of bismuth. Add ½ oz. of mercury. Add the white of an egg</i>	-	Brush	Millar (1899), Wager (1963)
<i>A powdered micaceous iron ore is mixed with cement, lime or plaster in a pasty or moist condition to which colouring matters may be added. A sample of the micaceous iron ore used (in the dry conditions consisted of: silicic acid and small stones (7.24%), iron oxide (Fe₂O₃, 80.17%), Aluminum oxide (5.16%), Calcium</i>	<i>Metallic lustre</i>	-	deBas (1920)

(Continued)

Table 3. Continued.

Description	Notes	Application	References
<i>Oxide (0.40%), sulphur in the form of sulphide (4.30%), Magnesia (1.33%), loss in calcining (1.28%), remainder (not determined, 0.12%). Objects made of this composition may be worked, just as stone, with a chisel without losing their metallic lustre. It may vary within the limits of 1 part of ore to 1 part of cement, lime or plaster and p. 1 of ore to p. 10 of cement, lime or plaster</i>			
<i>White shellac, an ounce in a pint of methylated spirit</i>	-	Brush or dip	Wager (1963)
<i>Dextrin, an ounce of powder dissolved in a pint of water</i>	-	Brush or dip	Wager (1963)
<i>Two ounces of beeswax heated and melted into half pint of glycerine, and thinned with turpentine</i>	-	Brush or dip	Wager (1963)
<i>Stearin or paraffin wax dissolved in turpentine, 1 ounce to half pint</i>	-	Brush or dip	Wager (1963)
<i>Paraffin or white wax or spermaceti in white spirit, petrol or petroleum</i>	-	Brush	Turco (1990)
<i>Waxy encaustics or aqueous wax emulsions (alone or with emulsions of white shellac and resins). Very concentrated or thickened with Arabic gum, alginates, methylcellulose, carboxymethylcellulose, animal glues, etc.</i>	-	Brush	Turco (1990)

p.=part(s), °C=Celsius degrees, °F=Fahrenheit degrees, °Bé =Baumé scale degrees. Quantities, concentration, and percentages are quoted from the original recipes. Most often it is not defined whether the % concentration is in weight or volume. The lack of detailed instruction in the original source could be overcome only by reproducing and testing the recipes.

silicate, both of which are insoluble compounds. Reissig suggested that this could be achieved [...] (1) by converting the lime sulfate into baryta sulfate and caustic or carbonate of lime, or (2) by changing the lime sulfate into lime silicate using potash silicate. [...] (Millar 1899; Kemp 1912).

According to Millar (1899), in 1878, F. von Dechend (1814-1890), of Bonn, obtained a patent for 'making plaster casts washable without injury' by using a solution of borax and alum and the subsequent application of soluble precipitates (salts of barium, calcium, and strontium).

An interesting review on the development of this technique was made by Payne (2020)¹¹, who cites Brannt and Wahl (1919) on two further methods and also discusses technological developments on the treatment of plaster casts through the invention of machines for the application of treatments during the nineteenth century.

Millar (1899) mentioned that Jacobsen¹² made the cast washable with lukewarm soap-water 'by immersing them or throwing upon them in a fine spray a hot solution of a soap prepared from stearic acid and soda lye in ten times its quantity, by weight, of hot water' and Shellhass¹³ made the recommendation of coating of plaster of Paris casts with a compound of finely powdered mica and collodion.

The purpose of **hardening** the surface can be achieved with different methods. Traditional methods were reported by Bankart (1908), Wager (1963), and others (Table 3), and numerous patents were filed with the declared purpose of providing a harder surface (Laxton 1887; Wolf 1901; Zolnay 1910).

In some cases, finishing is recommended without specifying the final result or purpose. For example, Millar (1899) and Wager (1963) describe 'a beautiful varnish': [...] by fusing ½ oz. of tin and ½ oz. of bismuth in a crucible. Melt together, then add ½ oz. of

mercury. When perfectly combined, take the mixture, allow it to cool, and add the white of an egg. The casts must be dry, and free from stains or dust [...].

Changing the appearance of the plaster surface could be done following numerous recipes, as summarised in Table 4 and the effects achieved can be as many as the materials available to the sculptor. To provide **good gloss**, for example, Millar (1899) suggests polishing with French chalk and cotton wool after coating the cast with a variety of materials.

Polychromed statues were also reproduced in plaster (Figure 7). Millar (1899) suggests colouring the surface of a cast by using water-colour when a dry surface is to be imitated (the watercolour might require several coats), and oil-colours when the surface is *moist* (his meaning is not clarified). Gypsum is ideal for the application of paint materials, but attention must be paid to the interaction between gypsum and paint (Bankart 1908; Turco 1990). Specific recipes to achieve a light-yellow (Frederick 1899) or lead (de Jonge 1985) coloured surfaces are easily obtained by traditional colouring methods.

While the purpose of colouring could be also to make the plaster white, or 'whiter' (Figure 7) (Frederick 1899; Millar 1899), often the surface was intended to mimic the material of the original object. Recipes for artificial stone, porcelain, wood, terracotta, marble, ivory, and metals (including gold, silver, and bronze, see Figure 8) were found in historical books and are quoted in Table 4. Chemical colouring, according to Turco (1990), can be obtained by using metal sulfates. Soluble colouring materials that do not provide colour through a chemical reaction, provide pale and weak shades after drying when applied to the plaster but can remain brighter if added to the mass of the plaster with any of the following materials: rubber, resins, silicates, fats, sodium casein, and glue (Merrifield 1846; Turco

Table 4. Recipes used to achieve the desired appearance onto a plaster cast surface.

Effect	Recipe	References
Artificial Stone	<i>(Patent) (1) Muriatic acid p. 40, tin p. 30, p. sal ammoniac 30. The tin is first dissolved in the acid, after which the sal ammoniac is incorporated in small pieces in the mixture. (2) Pulverised freestone p. 5, zinc oxide p. 20, pounded glass p. 15, powdered marble p. 10, calcined magnesia p. The above ingredients are intimately mixed and passed through a fine sieve so as to form a powder which is reduced to a pasty consistence with the above liquid (1), this paste being applied with a trowel to the surface (building front, inner or outer wall) which is to receive a damp proof covering, layer or coating. After a very short space of time this paste becomes very hard and assumes the appearance of stone and after being well set it is as hard as flint and has a smooth polished surface which can be rapidly painted if required in the ordinary way. Or I may mix any suitable coloring material, dye or pigment with the above powder (2) so as to impart to the hardened coating either a plain color or a marbled, veined or motley surface. [...] generally for all casting and moulding purposes for which plaster of Paris is generally used, my improved paste being manipulated in exactly the same manner as the latter and producing ornaments of fine appearance having a hard surface and being made to assume when required by the judicious addition of suitable colors the appearance of marble, granite or other ornamental stone</i>	Cléry (1896)
Bronze	500 l of water, 7 kg of alum, 6 kg of slaked lime, 1 kg of yellow ochre. To this mixture is added 1 kg of strong paste dissolved in 5 litre of hot water and 900 kg of gypsum and 450 kg of fine sand, free of clay, are diluted there	Turco (1990)
	(Bronze paint) mastic varnish and bronze powder	Frederick (1899)
	A coat, or coating of powder-colour mixed with milk or casein, followed by some slight polishing with cotton wool which has been dabbed into some talc (French chalk)	Auerbach (1961)
	Give the plaster cast a coat of white Polish. When this has dried thoroughly, pour some of the polish into a saucer and mix into it some burnt amber and give the cast a not too thick but free coating of this mixture. Now get some good gold-bronze powder of a full rich warm colour. Using a little of the white polish as a vehicle a dragging fresh bronze powder into it, touch up all the prominences of the cast with the gold bronze. If this operation has been carried out successfully, the cast will now have very much the appearance of a real bronze before being treated for colour. Then get a lump of beeswax and shred it finely into the top of a tin or other small receptacle, with a knife. Just cover this pile of wax shreds with some turpentine and leave it to soak overnight. By the next morning the wax should have dissolved, turning the mixture into a thickish and nearly transparent, somehow jelly-like substance. Into this solution, mix whatever colour you have in mind for the final bronze	Auerbach (1961)
	Artists' oil colour straight from the tube will serve well here; a Prussian blue with burnt sienna will give a rich green base with immense depth of tone whether it verges toward the olive or the blue side. Modification to the colour can of course be made by adding some yellow ochre or viridian. The whole mixture should be transparent rather than opaque. It is best to use a hog's hair brush for this operation and to spread the coloured wax very evenly and not too thickly, by stippling hard over the whole surface and into all the crevices. This will be shiny when wet and will become matt when dry. It can be then polished with a very soft cloth. When it is completely dry another polishing can be made with French chalk. If beeswax is not available almost any wax in paste form – not liquid – will serve	Auerbach (1961)
Colours	Need powder colour, burnt umber, emerald green, lamp black, reds and blues and a medium for floating these on. Use gold size (thinned with turpentine and linseed oil) or shellac. Need metal powders, bronzes, golds, coppers, medium cellulose lacquer or shellac. After bronzing, wax to protect	Wager (1963)
	Gold, silver or bronze paint can be bought in either liquid or solid form	de Jonge (1985)
	(Ancient bronze) p. 56 burnt shadow earth, p. 15 green, p. 5 Prussian blue, p. 15 Yellow ochre, p. 5 chrome yellow, p. 4 burnt Sienna earth diluted with p. 60 essence of turpentine, p. 25–30 copal paint and p. 10 drying oil. Treat first with shellac varnish and then with the aforementioned mixture. To emphasize more shiny areas, a wax dissolved in turpentine is added	Turco (1990)
	Soap solution (50 g of white soap in 500 g of water) is combined with a 10% copper sulfate solution and the green precipitate formed (copper soap), after filtration it is dried completely. The mixture is prepared: copper soap (p. 15), white wax (p.15) And linseed oil (p. 30) For which the pieces previously heated in a stove at 100–150 °C are treated. If you add 5–20% of iron sulfate, from bluish brown it becomes greenish brown. With this, the plaster becomes hard and waterproof	Turco (1990)
	Light yellow or buff is easily obtained by linseed oil, which tints the plaster, makes it resistant to water and durable and hard. The oil can be applied with a slightly tint (e.g. yellow ochre, raw sienna) or a wax like surface can be obtained (immersing the cast in warm oil for ten or twelve hours)	Frederick (1899)
	Water colours for a dry surface and oil colour for a dry one	Millar (1899)
	Shellac application before application of tempera' (dry powdered colour with the yolk of egg)	Bankart (1908)
	Lead colour is achieved by using graphite powder, asphalt lacquer, wax, black vinyl emulsion paint, turpentine-based oil	de Jonge (1985)
	For a yellow-brown colour dry the cast in the oven (80–90 °C) and then immerse it in oil or paint (50–60 °C); the plaster must be totally impregnated and subsequently dried in a well-ventilated area. It dips again for half the time and dries again	Turco (1990)
	Using metal sulfates. The plaster objects are soaked with diluted solutions of these salts, left to dry and then treated with barite water, sulphide or other barium or calcium salt. With the same metal acetates or sulfates, the plaster can be dyed by following their application by a treatment with phenolic dyes in alkaline ammoniacal medium or other alkaline earth hydrates. Oxidation colors such as pyrogallol, paraphenyldiamine, etc. They can be usefully applied by making alkaline or neutral solutions with the presence of catalysing substances and then exposing them to light.	Turco (1990)
	Soluble colouring materials remain more bright if added to the mass of the plaster with rubber, resins, silicates, fats, sodium casein, glue, etc.	Turco (1990)
	Greases penetrate gypsum deeply enough that they can be used to obtain good transparent dyes with a very pleasant, lively, very bright and washing-resistant effect. A fatty dye dissolves hot in a mixture of paraffin, stearin, spermaceti and similar substances, in which the pieces of plaster are immersed, keeping the temperature at 100 °C	Turco (1990)

(Continued)

Table 4. Continued.

Effect	Recipe	References
	<i>for half an hour. The mixture is left to cool down to 30–40 °C and heated to 100 °C again, repeating this operation three or four times. Dye and waterproofing are obtained simultaneously with grease and solvent dyes. The acid and substantive dyes in diluted solution of silicates, rubber, glue, sugar, dextrin, are ideal for surface work.</i>	
	<i>Good deep penetration of the colouring solutions is also obtained by first heating the pieces in the oven for 7–9 hours and then immersing the pieces for a few minutes in a saturated solution of potassium sulfate and then in a solution of: chromium alum, sulfate ferrous, zinc sulfate, manganese sulfate. After about 24 hours they withdraw and are left to dry in the air.</i>	Turco (1990)
Copper	<i>It is also known to mix the plaster with a metallic powder, for example with iron filings or finely divided zinc, and to treat objects cast or moulded of this material with a solution of metallic salt, in order to obtain a metallic, more particularly copper, external coating</i>	deBas (1920)
Gilding	<i>Gilding is often unsuccessful, but possible: gold leaf can be applied to any painted or shellacked surface and gold paint can be used for the details</i>	Frederick (1899)
Gloss	<i>4 lbs. of clean water, 1 oz. of pure curd soap, 1 ½ oz. pure white beeswax. Polish with cotton Boil p. 2 stearine, p. 2 Venetian soap, p. 1 pearl ash, p. 30 of solution of caustic potash and water</i>	Millar (1899) Millar (1899), Wager (1963)
Ivory	<i>Rub the surface with paraffin or wax candle and polishing with silk. Beeswax with an equal amount, or a little more, of turpentine, gives a good finish</i>	Frederick (1899)
	<i>White wax dissolved in olive oil, or paraffin wax. Polish with French chalk and cotton wool. If the polished casts are left in a smoky room</i>	Millar (1899)
	<i>Two coats of clear linseed oil, and kept for a while in a smoky room</i>	Millar (1899)
	<i>To apply a coat or coatings, of white polish alone, is the simplest method of giving a slightly ivory and polished appearance to the cast. A little raw umber, yellow ochre or other colour may be added to the polish to give to the polish to give variety and warmth.</i>	Auerbach (1961)
	<i>Little yellow ochre, raw umber or black, applied sparingly just before the final polish, will give an old ivory effect. Rub the colour well into the hollows and wipe off high spots. [...] A final polish with French chalk will give a good lustre. Heat the plaster cast and dip it in stearic acid</i>	Wager (1963) de Jonge (1985)
	<i>Indispensable to have gypsum plaster or very white gypsum, the objects must be heated in the oven at 100–120 °C to make them anhydrous and favour the penetration of waxy substances. They are immersed in a paraffin or stearin bath with spermaceti. The yellowish shade is obtained by dyeing the waxes with traces of bitumen or aniline dyes with fats or Judean bitumen dissolved in turpentine essence</i>	Turco (1990)
Marble	<i>A smooth surface can be obtained by mixing the plaster with a weak solution of gum Arabic. It will have a marble appearance if saturated with milk. Melted stearin can be applied. The finest quality of plaster mixed with turpentine can be used as a paint</i>	Frederick (1899)
	<i>Clean skimmed milk, and with a clean soft brush coat the figure until it will absorb no more. Gently blow off all superfluous milk from the face of the object. Plaster gauged with milk and water will enable the casts to be polished.</i>	Millar (1899)
	<i>Heated bath composed of a solution of brimstone and boiled linseed-oil or equivalent oil (in some cases the oils might be omitted). When the articles remain a sufficient time in the heated bath, they are taken out and put into an oven heated to about from 125 °C to 150 °C and allowed to remain there two or three days, and gradually cooled off; or they may be put in paper when taken out of the bath and allowed to stand for about a week in an airy room. After this the articles are polished by the same process as marble is polished, they taking a very high and smooth polish similar to it. I may add that in experimenting I have added litharge, glue, soda-ash, or potash to the brimstone for boiling the composition in; but I prefer the brimstone alone, or it and boiled linseed or equivalent oils or varnish</i>	Trickey (1884)
	<i>The basic acetates of metallic salts provide the most stable and pleasant colours and also the most suitable for imitating marble</i>	Turco (1990)
Porcelain	<i>White plaster is mixed with magnesium oxide (or zinc) and after complete hardening the pieces formed are drenched with a solution of phosphoric acid or with calcium acid phosphate. Excellent results are also obtained with aluminium oxide or alumina</i>	Turco (1990)
Silver	<i>Finely ground mica powder mixed with colloid</i>	Frederick (1899)
Terracotta	<i>Venetian, light or Indian red. It is better to give the cast a coat of white polish first. Start by applying the main colour desired opaquely and then work over the top of this colour with very thin washes, glazes or scumbles of lighter colours, finally using just a little French chalk and a wad of cotton wool. Alternatively, a little powder colour mixed with some glue size to hold it together and a little gilders' whiting (or a touch of Titanium white)</i>	Auerbach (1961)
	<i>The plaster is mixed with slaked fat lime in small quantities and mixed with a dilute solution of iron sulfate. Particular nuances can be obtained with further surface treatments</i>	Turco (1990)
White	<i>[...] White lead thinned with turpentine is preferred by many to zinc white. [...] Lead does not have the whiteness of the zinc, but it can be applied much more quickly</i>	Frederick (1899)
	<i>Give it a coat of linseed oil, and give another coat, and French polish. Make smooth with white size, and varnish with hard white varnish.</i>	Millar (1899)
Wood	<i>To make a model look like wood, varnish the plaster with wax or wood stain</i>	de Jonge (1985)

p.=part(s), °C=Celsius degrees. Quantities, concentration, and percentages are quoted from the original recipes. Most often is not defined whether the % concentration is in weight or volume. The lack of detailed instruction in the original source, could be overcome only by reproducing and testing the recipes.

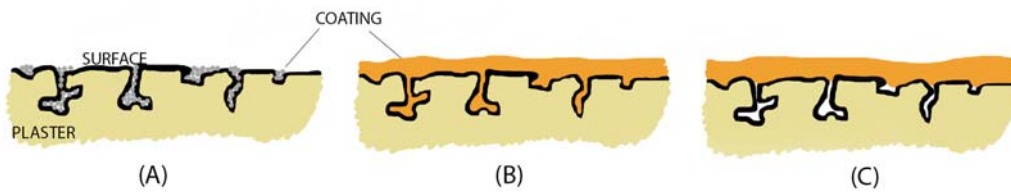


Figure 6. Simplified drawing representing the possible interactions of the coating with the porous plaster surface. The material applied onto the surface can penetrate the pores without forming a film (A), penetrate the pores and form a film on the surface (B), or form a film without penetrating the surface (C).



Figure 7. Left: A plaster cast of an effigy of Isabella of Angouleme (REPRO.A.1938-4). Painted plaster cast. Right: Plaster cast from one of the shields on the Royal Albert Hall (REPRO.1901-16). White plaster cast. © Victoria and Albert Museum, London/as specified by the rights holder. Source: V&A's Collection Management System.



Figure 8. Left: A plaster cast of a *putto* (REPRO.1888-519). The plaster is finished to resemble bronze. Right: A plaster cast of a font (REPRO.1877-1). The plaster is finished to resemble gold. © Victoria and Albert Museum, London/as specified by the rights holder. Source: V&A's Collection Management System.

1990). Non-volatile substances, such as oils and fats, can carry dyes and artificial organic colourants deep into the plaster. These substances also contribute to improving the surface resistance of gypsum plaster products. The acid and dyes in a dilute solution with silicates, rubber, glue, sugar, or dextrin, are also ideal for surface work (Turco 1990).

Conclusion

Archival research associated with technical art history and conservation is a fairly new field. Although several research groups are focusing on this topic now, the field is still quite uncharted. By combining thorough archival research with the technical investigation, it is possible to unveil the technologies and manufacturing practices of the past. The review presented in this paper offers a summary of historical coating techniques for the use of artists, conservators, curators, and scientists. The review of the technical literature supports our understanding of what the coatings are and the justification of their existence and function; nevertheless, the reality of understanding the surface of casts is far more complicated. Scientific analysis is key to providing an accurate picture case by case, corroborating or demystifying what authors have written around plaster casts and their appearance.

The holistic understanding of plaster casts and casting techniques, together with the recipes and substances associated with the treatment of their surfaces, is essential to investigate their condition. Surface coatings are an inherent part of plaster casts encapsulating the history of their original function, their making, and makers, as well as their more recent past. The awareness of their relevance is key towards establishing the appropriate conservation and curatorial strategies to guarantee their preservation for future generations.

Notes

1. The Museum nos. can be used to find the objects in the V&A Website - Search the Collections (2020).
2. Original results related to the scientific examination of the V&A casts are forthcoming.
3. The importation into English of the Italian term *stucco* and its plural anglicisation *stuccoes*, instead of the Italian plural *stucchi*, shows the lack of appropriate terms for the materials used by plasterers in the English language. To further muddle communication, the terminology in plasterwork was also used with different meanings over time, and it is only in English that the word *stucco* can be rightly used for both decorative plasterwork and architectural renders (Gapper 1999).
4. Plinio, *Naturalis Historia*, XXXIII, 156-157, quoted in P. Toesca, 'Calco', in *Enciclopedia italiana Treccani*, Rome 1949, vol VIII, pp. 540.

5. The definition of a 'sense of a shared past' was necessary for the building of a feeling of community, based on analogies between a distant past and the present. 'This shared past was shaped and manipulated by the contemporary political and economic aspirations, often resulting in the stereotyping and simplification of an imagined past.' (Fehlmann 2007).
6. More precisely, Turco (1990) indicates 128 °C for a first step of the reaction, where the dihydrate sulfate loses 75% of the crystallization water and a second step, occurring at 163 °C, where all the water is lost. Heating further, at about 500–600 °C, *gesso morto* (dead gypsum) is obtained, and it does not absorb water. Heating at 1000 °C, there is the formation of up to 3% of calcium oxide (quicklime, CaO). At 1360 °C the material melts and at 1375 °C complete dissociation occurs.
7. Leonard Alexander Desachy (1845-1864), French modeler who patented fibrous plaster casting in 1856.
8. A coloured layer of plaster is used to indicate where the interface between the mould and the cast is. Kemp (1912), for example, suggests the use of some powder colour – yellow ochre, burnt umber, or light red – to tint the first coat of plaster.
9. The source does not indicate a definition of this material. In modern days this would be understood as polyvinyl acetate (PVA) adhesive, however here it likely refers to some type of purified or 'bleached' animal glue.
10. Turco (1990) suggests that more modern solutions of elastic rubber or natural and synthetic rubber provide an insulating property, having however a limited duration after exposure to light and heat, whereas silicones applied onto the surface provide stability to cold, heat, oxidation, and water repellence.
11. While Payne's work includes a discussion of the treatment of classical casts that were transferred from V&A to BM in 1907, study so far, of casts of later European works, has not revealed conclusive evidence that these coatings were applied across the V&A collection.
12. It is unclear who is the person mentioned by Millar. It could be Jens Peter Jacobsen (1847 – 1885, Danish novelist, poet, and scientist), Antonio Nicolo Gasparo Jacobsen (1850 – 1921, Danish-born American maritime artist) or David Jacobsen (1821 – 1871, Danish artist).
13. No reference found; it is not clear who is mentioned by Millar.

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